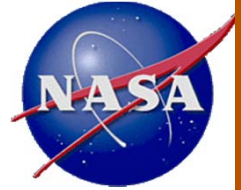


National Aeronautics and Space Administration



Orbital Debris Environment – Now and the Future

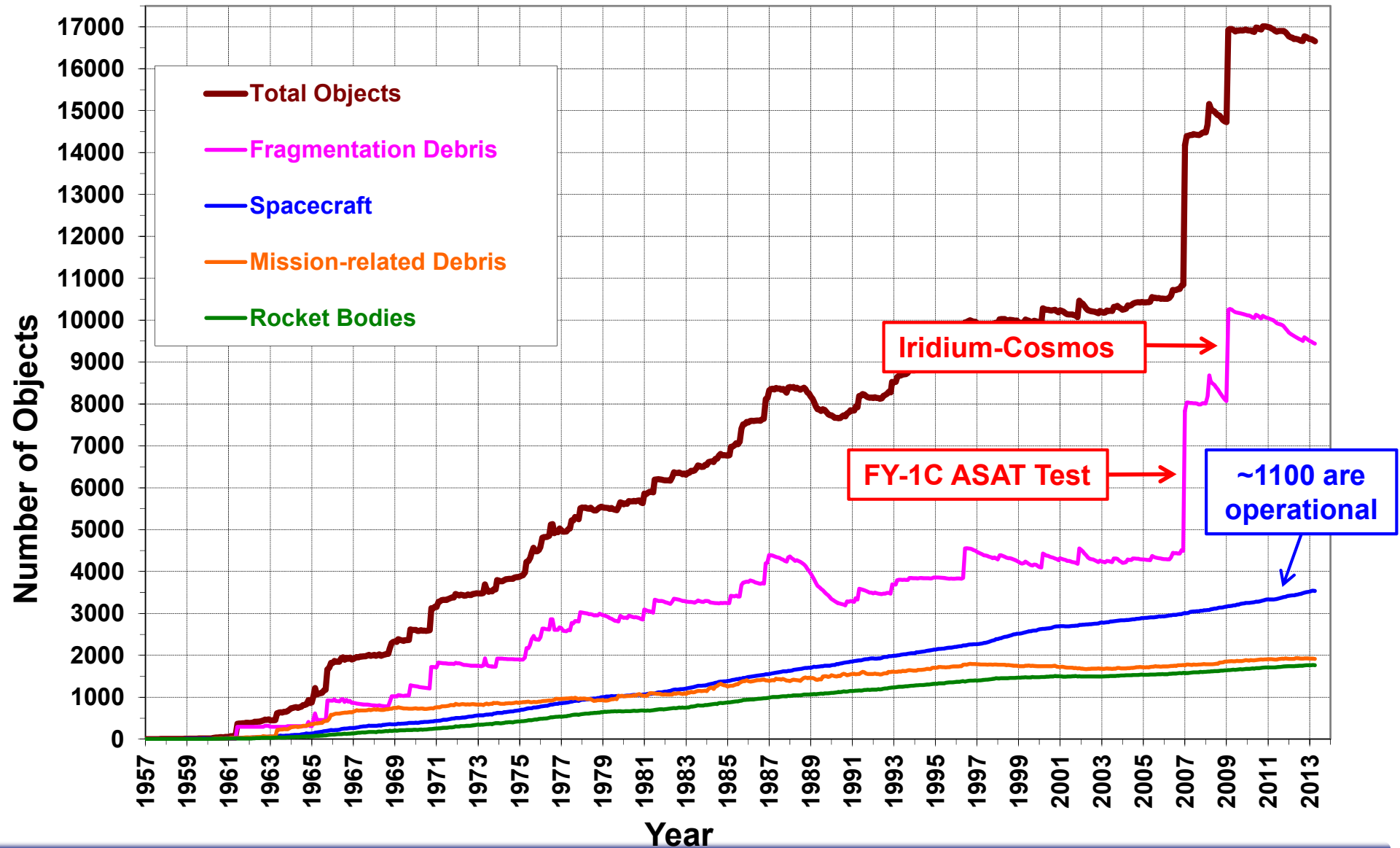
**J.-C. Liou, PhD
NASA Orbital Debris Program Office
NASA Johnson Space Center, Houston, Texas**

**“Space Debris and Space Operations: The Next 30 Years” Panel Session
AIAA SPACE 2013 Conference, San Diego, 12 September 2013**



Growth of the Cataloged Populations

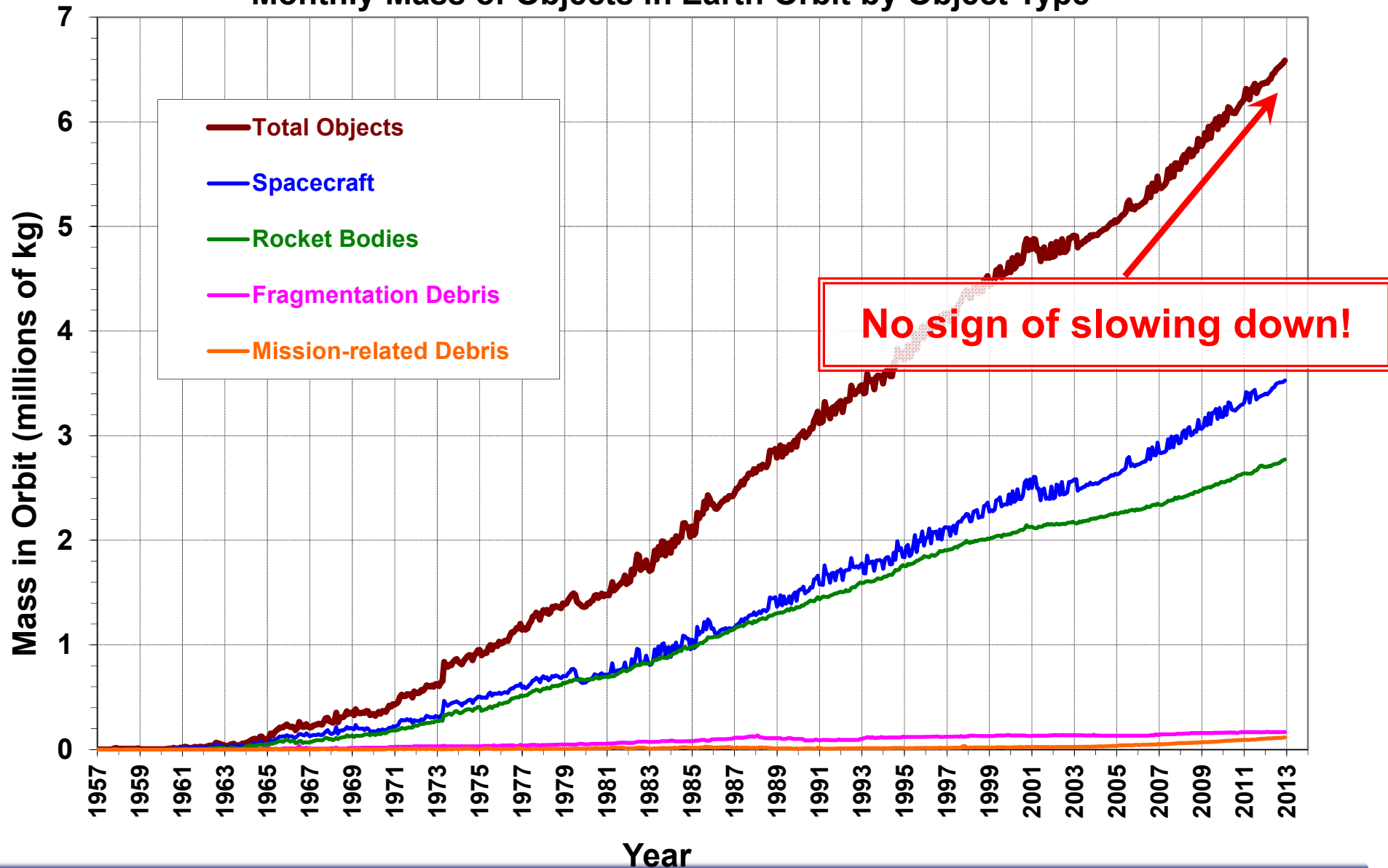
Monthly Number of Objects in Earth Orbit by Object Type





Mass in Space

Monthly Mass of Objects in Earth Orbit by Object Type





How Much Junk Is Currently Up There?

**Softball size or larger (≥ 10 cm): ~20,000 to 22,000
(tracked by the U.S. Space Surveillance Network, SSN)**



Marble size or larger (≥ 1 cm): ~500,000



**Dot or larger (≥ 1 mm): >100,000,000
(a grain of salt)**

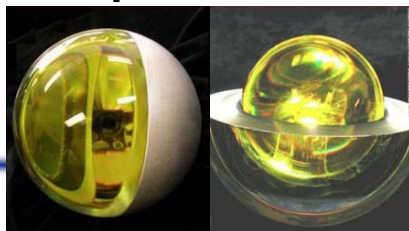
- Due to high impact speed in space (~10 km/s in LEO), even sub-mm debris pose a realistic threat to human spaceflight and robotic missions
 - 1-cm Al sphere @ 10 km/s = 400 lb safe @ 60 mph
 - 5-mm Al sphere @ 7 km/sec could penetrate a 2.54 cm thick Al wall
- Total mass: ~6300 tons LEO-to-GEO (~2700 tons in LEO)



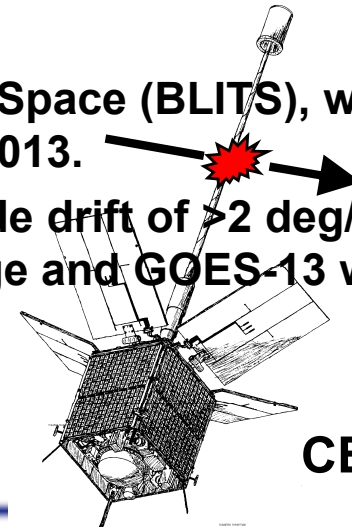
Threat From Orbital Debris

- **Is the threat from orbital debris real?**

- The gravity-gradient boom of an operational French satellite (CERISE) was cut in half by a tracked debris in 1996
- The fully operational iridium 33 was destroyed by a retired Russian satellite Cosmos 2251 in 2009
- Near the end of the Space Shuttle Program, the Loss of Crew and Vehicle risks from MMOD impact damage were in the range of 1 in 250 to 1 in 300 per mission (OD to MM ~ 2:1 at ISS altitude)
- Impacts by small, untracked debris could be responsible for many satellite anomalies
 - A 17-cm Russian retro reflector, Ball Lens In The Space (BLITS), was damaged and shed a piece of trackable debris in January 2013.
 - The U.S. GOES-13 Satellite experienced an attitude drift of >2 deg/sec in May 2013. Fortunately there was no permanent damage and GOES-13 was returned to normal operations in June.



BLITS



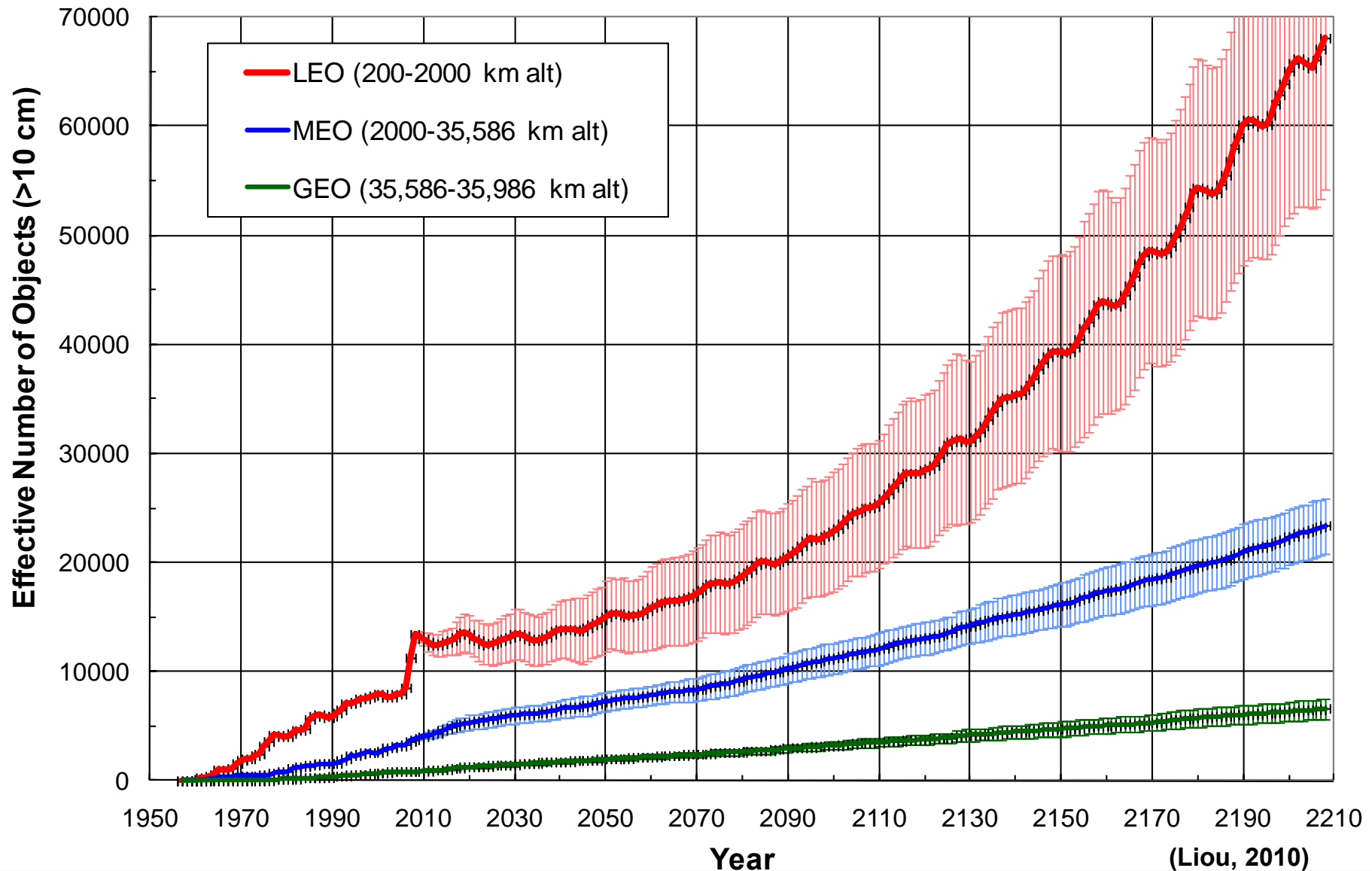
CERISE



Future Projection – The Worst Case Scenario

(Regular Satellite Launches, **Without Mitigation Measures**)

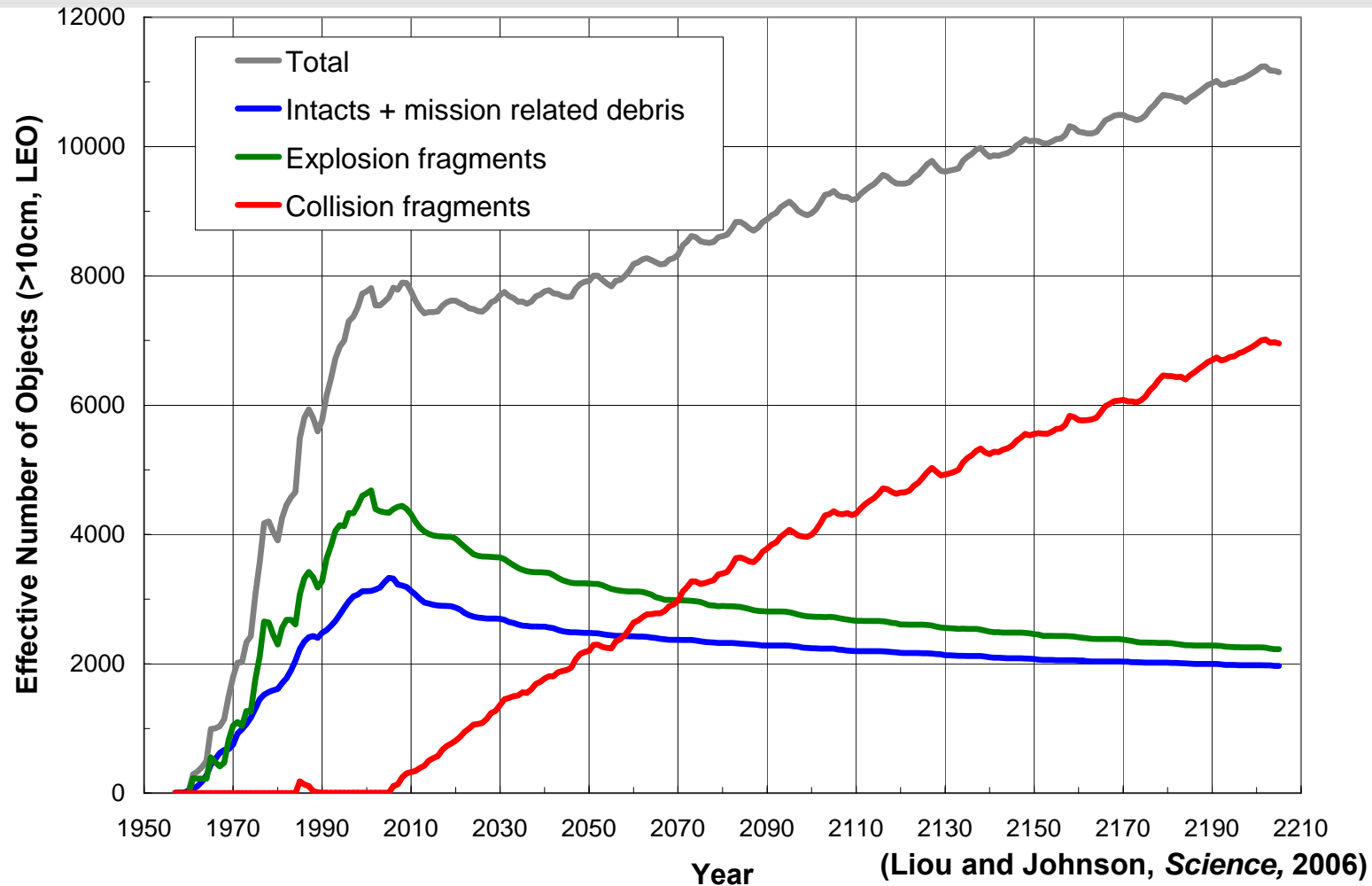
Non-Mitigation Projection (averages and 1- σ from 100 MC runs)





Future Projection – The Best Case Scenario

(No New Launches Beyond 1/1/2006)



- Collision fragments replace other decaying debris through the next 50 years, keeping the total population approximately constant
- Beyond 2055, the rate of decaying debris decreases, leading to a net increase in the overall satellite population due to collisions



International Consensus

- **Future orbital debris population growth in LEO has been investigated by the Inter-Agency Space Debris Coordination Committee (IADC) since 2008**
- **An official comparison study was completed in 2012**
 - The objectives were to confirm the instability of the current LEO debris population and to reach a consensus on the need to use active debris removal to stabilize the future LEO debris environment
 - Study participants: ASI, ESA, ISRO, JAXA, NASA (lead), UKSA
 - Results from the six different models are consistent with one another: (1) even with no future explosion and a global 90% compliance of the 25-year rule, the LEO debris population is expected to increase in the next 200 years and (2) catastrophic collisions involving intact objects are likely to occur every 5 to 9 years

Inter-Agency Space Debris Coordination Committee



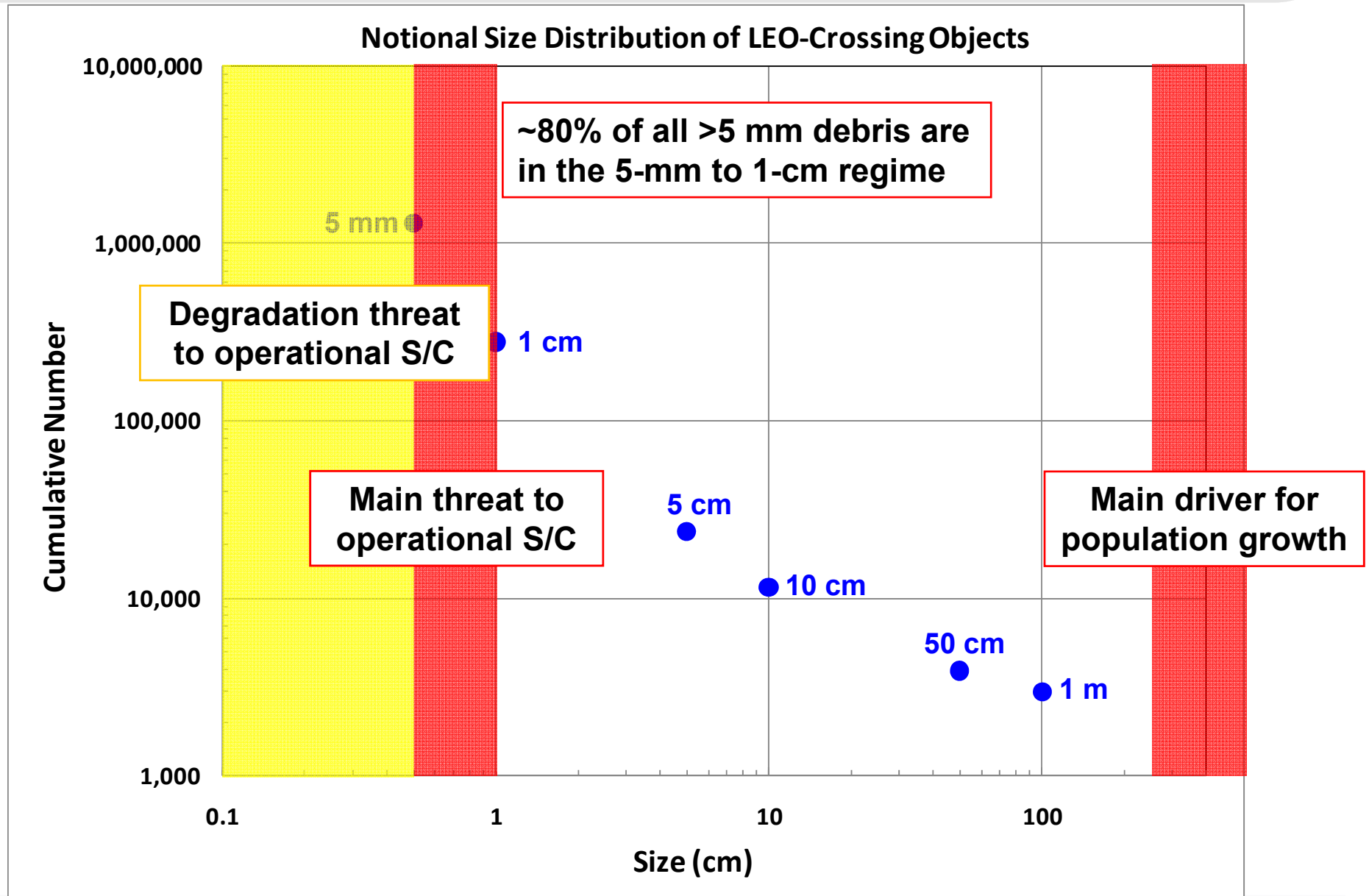


Problems and Solutions

- **LEO debris population will continue to increase even with a good implementation of the commonly-adopted mitigation measures**
 - The root-cause of the increase is catastrophic collisions involving large/massive intact objects (rocket bodies and spacecraft)
 - The major mission-ending risks for most operational spacecraft, however, come from impacts with debris just above the threshold of the protection shields (~5-mm to 1-cm)
- **A solution-driven approach is to seek**
 - Concepts for removal of massive intacts with high $P_{\text{collision}}$
 - Concepts capable of preventing collisions involving intacts
 - Concepts for removal of 5-mm to 1-cm debris
 - Enhanced impact protection shields for valuable space assets



Threat Regimes





Challenges for the Next 30 Years

- **Environment management**
 - Improve global compliance of orbital debris mitigation measures
 - Invest in innovative concepts and technologies for long-term remediation of the near-Earth orbital debris environment
- **Risk mitigation**
 - Increase the capabilities in space situational awareness to identify and track the majority of ~cm debris with good accuracy
 - Develop cost-effective, low mass impact shields against mm-to-cm orbital debris